HoTT-RO v2

Applications Beyond the Original Project

Waldemar Lis — April 2026

1. The Instrument

HoTT-RO v2 is a formal system consisting of Martin-Lof Type Theory extended by two axioms: the Univalence Axiom (UA, standard in Homotopy Type Theory) and the Axiom of Flat Mutuality (AFM, new). It was built as a mathematical instrument for the relational ontology proposed in *The Self-Experiencing Universe* (Lis, 2025). The system was used to support nineteen simulations, a falsifiable empirical prediction, and six dynamics validation tests. **HoTT-RO v2** was built **STRICTLY for relational ontology, and that is where it is irreplaceable** — the full apparatus works as an integrated whole. Beyond the original project, it has two strong external applications (relational quantum mechanics and immunology) where it addresses specific formal gaps that existing tools do not fill. For the remaining domains analyzed below, it offers descriptive precision rather than necessity.

This document asks a different question: where else can **HoTT-RO v2** be applied? The answer depends entirely on which formal properties of the system are required by a given domain. Not every domain needs all of them. Some domains need only UA. Some need AFM. Some need the full apparatus including IT-Region, Depth, and path-based identity. The analysis below is organized by domain, with each entry specifying exactly which formal properties are relevant and why.

2. Formal Properties Available for Transfer

Property	What it does	What it replaces
UA (Univalence Axiom)	Structural equivalence between types IS identity. Two configurations with equivalent relational structure are identical as types, regardless of substrate.	Set-theoretic identity based on membership. Classical identity as a binary fact.
AFM (Axiom of Flat Mutuality)	Mutual specification between types is symmetric across the universe hierarchy. Neither side of a constitutive relation is prior.	Hierarchical asymmetry in standard HoTT. Any framework where one side of a relation is 'more fundamental.'
Path-based identity	Identity is not binary (same/different) but graded: the path between two configurations has length, direction, and properties.	Classical identity as a yes/no question. Any framework that cannot express 'how different' two things are structurally.
IT-Region (Integration Threshold)	A topological region in parameter space defined by conjunction of conditions. Systems can be at the boundary, inside, or outside. Continuous, not binary.	Sharp thresholds, binary classifications, arbitrary cutoffs.
Depth	How far inside the IT-Region a configuration sits. Determined by the weakest parameter (bottleneck principle).	Scalar measures that average across dimensions rather than identifying the limiting factor.

RC as descent (Radical Contextuality)	Identity is fully determined by local relational context. Change the context, change what the thing is — not what it does.	Intrinsic properties, essential natures, context-independent identity.

A domain is a candidate for **HoTT-RO v2** if and only if it requires at least one of these properties and standard mathematical frameworks do not provide it. If classical mathematics works — use classical mathematics.

3. Domain-by-Domain Analysis

3.1 Relational Quantum Mechanics (Rovelli)

Carlo Rovelli's relational interpretation of quantum mechanics (1996) proposes that quantum states do not exist absolutely — they exist only relative to an observer. There is no 'state of the system in itself.' A measurement outcome is a fact relative to the measuring system, and a different observer may assign a different state to the same system. This is not epistemic (not about what we know) — it is ontic (about what exists).

What provides: HoTT-RO v2

UA formalizes the claim that two quantum descriptions with equivalent relational structure are identical as types — not merely 'corresponding' or 'equivalent for practical purposes.' This is stronger than what standard quantum formalism provides, where equivalence between descriptions in different reference frames is typically handled by unitary transformations that preserve the Hilbert space structure but do not make an identity claim at the ontological level.

AFM provides what standard HoTT cannot: the guarantee that the observer-observed relation is symmetric. In standard HoTT, the universe hierarchy introduces structural asymmetry — a type in U(n) and a type in U(m) are not on equal footing. Rovelli's interpretation explicitly requires that neither side of the measurement relation is prior. AFM closes this gap by decree: mutual specification is symmetric regardless of universe level.

Path-based identity provides a natural formalization of the fact that two observers may assign different quantum states to the same system. The 'distance' between their descriptions is a path in type space — it has structure, direction, and can be composed. To be clear about scope: **HoTT-RO v2** gives RQM formal precision and protection against internal inconsistency. It does not change any experimental prediction. The only domain where this formalization could potentially touch empirical consequences is quantum gravity — where the question of observer symmetry becomes a constraint on which formal approaches are viable — but this remains open speculation, not a claim.

Properties used: UA, AFM, path-based identity.

Properties not needed: IT-Region, Depth (no threshold structure in RQM).

> ***Fit: STRONG. AFM addresses a specific formal gap that no existing formalization of RQM fills. This is the single most natural application of HoTT-RO v2 outside the original project.***

3.2 Immunology: Self/Non-Self Discrimination

The immune system distinguishes 'self' from 'non-self' — but this distinction is not based on intrinsic properties of molecules. It is based on relational context: how a molecule interacts with immune receptors, what signaling environment it appears in, and what the system's prior exposure history is. The same molecule can be tolerated in one context and attacked in another. Autoimmune disease occurs when the threshold between self and non-self shifts — the system begins treating its own configurations as foreign.

What provides: HoTT-RO v2

Radical Contextuality (RC as descent condition) formalizes the claim that immune identity is not a property of the antigen but of the antigen-in-context. Change the context — change whether the molecule is 'self.' This is precisely what RC says: identity is constituted by local relational context, not by intrinsic features.

IT-Region provides a model for the tolerance threshold. The immune system does not have a binary switch between 'tolerate' and 'attack.' There is a continuous region of tolerance, with a topological boundary. Systems near the boundary (subclinical autoimmunity, transplant tolerance) are formally near the boundary of the IT-Region. Depth measures how far inside tolerance a configuration sits — and the bottleneck principle identifies which parameter is the limiting factor (e.g., regulatory T-cell count vs. antigen presentation efficiency vs. cytokine environment).

AFM is relevant in one specific context: the mutual specification between the immune system and the organism it protects. The immune system constitutes the organism's identity boundary, and the organism's tissue constitutes the immune system's 'self' reference. Neither is prior. AFM formalizes this symmetry.

Properties used: RC (descent), IT-Region, Depth, AFM.

Properties not needed: UA is useful but not essential (cross-substrate comparison is not the core need).

> ***Fit: STRONG. Immunology has a genuine formal gap: the self/non-self distinction is known to be contextual, threshold-based, and non-binary, but existing models (danger theory, network theory) lack formal tools for continuous thresholds with bottleneck dynamics. HoTT-RO v2 provides these natively.***

3.3 Ecology: Ecosystem Identity and Resilience Thresholds

In an ecosystem, the 'identity' of a species is not determined by its genome alone but by its relational position in the food web, its mutualistic and competitive interactions, and its functional role. The same species can play fundamentally different roles in different ecosystems. Remove a keystone species, and the identities of other species shift — not just their behavior, but what they functionally are.

Ecosystem resilience exhibits threshold behavior. An ecosystem can absorb perturbation up to a point, then undergoes a regime shift — a qualitative reconfiguration from which return to the previous state is not straightforward. Coral reef bleaching, savanna-forest transitions, and lake eutrophication are empirically documented examples.

What provides: HoTT-RO v2

RC formalizes the relational constitution of ecological identity. UA justifies cross-ecosystem structural comparison: two ecosystems with equivalent relational structure (food web topology, functional group distribution) are structurally identical regardless of the specific species involved. This is not a metaphor — it is the formal statement that structural equivalence IS identity.

IT-Region models resilience thresholds. An ecosystem is 'inside' the resilience region when all relevant parameters (biodiversity, connectivity, redundancy) simultaneously exceed their minima. Depth identifies the weakest parameter — the bottleneck that will fail first under stress. This is directly useful: conservation biology needs to know not just 'is this ecosystem at risk' but 'which specific parameter is the limiting factor.'

AFM is relevant for mutualistic relationships (pollinator-plant, cleaner fish-host) where neither side is ontologically prior in constituting the relationship.

Properties used: RC, UA, IT-Region, Depth, AFM (for mutualisms).

> ***Fit: MODERATE-STRONG. Ecology already has good quantitative models for some of these phenomena (network analysis, resilience theory). HoTT-RO v2 would add formal ontological grounding — the ability to say why structural equivalence matters, not just that it does. The added predictive value over existing ecological models is uncertain.***

3.4 Developmental Biology: Cell Identity and Differentiation

A stem cell's identity is constituted by its signaling environment — the specific relational context of growth factors, cell-cell contacts, and extracellular matrix interactions. The same genome produces a neuron in one context and a skin cell in another. This is Radical Contextuality in biological form. Differentiation thresholds — the points at which a cell commits to a lineage — behave like IT-Regions: multiple conditions must be simultaneously met.

What provides: HoTT-RO v2

RC provides the formal statement that cell identity is not genomic but relational. IT-Region models differentiation commitment as a topological region with a continuous boundary. Depth measures how committed a cell is to a lineage — with the bottleneck principle identifying the limiting factor (e.g., is it the transcription factor concentration, the cell-cell contact, or the matrix stiffness that is closest to the threshold?).

UA justifies comparing differentiation processes across organisms: if the relational structure of the signaling environment is equivalent, the differentiation outcome is structurally equivalent, regardless of the specific molecular substrate.

Properties used: RC, IT-Region, Depth, UA.

Properties not needed: AFM (differentiation is typically asymmetric — signaling environment determines cell fate, not vice versa).

> ***Fit: MODERATE. Developmental biology has mature models (Waddington landscape, morphogen gradients, Turing patterns). HoTT-RO v2 would provide elegant re-description with formal ontological grounding but uncertain added predictive value. The IT-Region + Depth model could be genuinely useful for understanding multi-factor differentiation thresholds.***

3.5 Network Economics: Relational Value and Platform Identity

In network economics, the value of a node (firm, currency, platform) is not intrinsic — it is constituted by its position in a network of transactions, users, and dependencies. Bitcoin has no 'intrinsic value' — it has a relational position. A platform's identity (what it 'is') changes when its user base, API ecosystem, or regulatory environment changes. This is not a metaphorical observation — it is a structural fact that network economists state informally but cannot formalize precisely.

What provides: HoTT-RO v2

RC formalizes the relational constitution of economic identity. AFM is directly relevant: in a decentralized network, no node is ontologically prior. The buyer constitutes the seller's identity as much as the seller constitutes the buyer's. General equilibrium theory treats supply and demand symmetrically at the formal level, but many applied models (Keynesian demand-driven, supply-side, platform economics with privileged hubs) introduce structural asymmetries. AFM provides a formal guarantee of flatness that is not standard in these frameworks.

IT-Region models network viability thresholds. A platform survives when multiple parameters (user count, transaction volume, developer engagement) simultaneously exceed minima. Depth identifies which parameter is the bottleneck — the one that will kill the platform first.

Path-based identity allows measurement of 'how different' two market states are, structurally — not just 'are they the same or different.'

Properties used: RC, AFM, IT-Region, Depth, path-based identity.

> ***Fit**: MODERATE. Network economics already has quantitative tools (graph theory, mechanism design). HoTT-RO v2 adds ontological precision — especially AFM for truly decentralized systems where no node should be privileged. Practical adoption depends on whether economists see value in formal ontological grounding beyond their existing quantitative tools.*

3.6 Distributed Systems and Consensus Protocols

In decentralized networks (blockchain, distributed databases), node identity is constituted by connections and transaction history. Consensus is the process by which nodes with different local information converge on a shared state. The fundamental requirement is that no node is privileged — the protocol must be flat.

What provides: HoTT-RO v2

AFM formalizes the flatness requirement. Path-based identity could model convergence: the distance between two nodes' local states is a path that the consensus protocol aims to shrink.

However, this application uses perhaps 20-25% of the apparatus. RC, IT-Region, Depth, and most of the derived definitions are not needed. The formal tools that distributed systems already have (Byzantine fault tolerance, Paxos, Raft) operate at a different level of abstraction.

Properties used: AFM, path-based identity.

> ***Fit**: WEAK. The fit is real but thin. Most of the apparatus is unused. Existing formal tools for distributed systems are mature and purpose-built. HoTT-RO v2 would be an over-engineered solution for this domain.*

3.7 Social Ontology: Institutional and Social Identity

Social identity — what a person 'is' in a social context — is relationally constituted. A professor is a professor because of their relation to a university, students, a discipline, and credentialing institutions. Change the relational context and the identity changes. Social roles are not intrinsic properties of individuals.

Institutional identity has the same structure. A university 'is' what it is because of its relations to students, faculty, funding bodies, accreditation agencies, and peer institutions. These relations are mutually constitutive — the university constitutes the professor's identity as much as the professor constitutes the university's.

What provides: HoTT-RO v2

RC formalizes the relational constitution of social identity. AFM captures the mutual constitution of institutional relationships (university-professor, state-citizen, platform-user). UA enables structural comparison across different institutional configurations: two institutions with equivalent relational structure are structurally identical regardless of name, location, or history.

IT-Region could model institutional viability: an institution exists as a functioning entity only when multiple relational conditions are simultaneously met. Depth identifies the weakest link.

Properties used: RC, AFM, UA, IT-Region, Depth.

> ***Fit**: MODERATE. Social ontology is an active philosophical field (Searle, Tuomela, Gilbert) with existing frameworks. **HoTT-RO v2** would provide a more formally precise language than currently available, but social ontologists may resist the mathematical apparatus. The added value is in precision, not in new predictions.*

3.8 Philosophy of Biology: Species Identity

The species problem — what makes a species a species — is one of the longest-running debates in philosophy of biology. Species concepts include biological (reproductive isolation), ecological (niche), phylogenetic (common descent), and morphological (form). Each captures a different relational aspect. No intrinsic property defines a species.

What provides: HoTT-RO v2

UA says: two populations with equivalent relational structure (equivalent ecological roles, equivalent reproductive patterns, equivalent phylogenetic positions) are structurally identical as types — they are the same species in the structural sense, regardless of morphological differences. This formalizes what convergent evolution demonstrates empirically: different substrates, same relational structure, same functional identity. A caveat: UA says 'if structures are equivalent, then identical' — but whether two populations' structures are equivalent depends on the level of description at which the comparison is made. At coarse grain, a bat wing and a bird wing are equivalent; at fine grain, they are not. **HoTT-RO v2** provides the formal tool for comparison but does not determine the appropriate grain of analysis. That remains a biological question.

RC formalizes the context-dependence of species identity. Path-based identity allows species to be 'more or less different' from each other structurally, rather than being binary categories.

Properties used: UA, RC, path-based identity.

> ***Fit**: MODERATE. The species problem is conceptual, not computational. **HoTT-RO v2** offers a precise language for expressing relational species concepts but does not resolve the underlying biological disagreements about which relations matter most.*

4. Where HoTT-RO v2 Does Not Apply

HoTT-RO v2 adds value only when identity is relationally constituted, equivalence is structural, and flat mutuality is required. In domains with stable, intrinsic, absolute identity, standard mathematics is sufficient and **HoTT-RO v2** is unnecessary overhead.

Domain	Why HoTT-RO v2 is not needed
Classical mechanics	Objects have stable, intrinsic identity. A billiard ball is a billiard ball regardless of relational context. Newton's laws work.
Most of chemistry	Molecular identity is determined by atomic structure. Water is H_2O everywhere. Relational context matters at edges (catalysis, solvation) but the core identity is intrinsic.
Engineering	Components have specified, context-independent properties. A steel beam's tensile strength does not depend on what building it is in. Classical mathematics is precisely right.
Pure mathematics (internal)	Mathematical objects within standard foundations have well-defined identity. **HoTT-RO v2** is a tool for applied ontology, not for internal mathematical work (standard HoTT already exists for that).
Classical logic and computation	Boolean identity (true/false) is binary and context-independent. Path-based graded identity is not needed. Standard computer science foundations are adequate.

The general principle: if the domain's practitioners do not already complain that identity is context-dependent, that thresholds are poorly formalized, or that standard mathematics forces asymmetries that should not be there — **HoTT-RO v2** is a solution looking for a problem.

5. Summary

Domain	Fit	Key properties	Added value over existing tools
Relational QM (Rovelli)	STRONG	UA, AFM, paths	AFM fills a specific formal gap: observer-observed symmetry. No existing formalization provides this.
Immunology (self/non-self)	STRONG	RC, IT-Region, Depth, AFM	Continuous thresholds with bottleneck dynamics for self/non-self discrimination. Existing models lack this.
Ecology (resilience)	MOD.-STRONG	RC, UA, IT-Region, Depth, AFM	Ontological grounding for ecosystem identity and resilience thresholds. Existing ecology is strong; added predictive value uncertain.
Developmental biology	MODERATE	RC, IT-Region, Depth, UA	Multi-factor differentiation thresholds with bottleneck ID. Existing models mature; adds formal precision.
Network economics	MODERATE	RC, AFM, IT-Region, Depth	Formal flatness (AFM) for decentralized systems. Graph theory covers most quantitative needs.
Social ontology	MODERATE	RC, AFM, UA, IT-Region	Formal precision for relational social identity. Existing social ontology less formalized; resistance to apparatus likely.
Phil. of biology (species)	MODERATE	UA, RC, paths	Formal language for relational species concepts. Does not resolve underlying biological disagreements.

Distributed systems	WEAK	AFM, paths	Uses ~20% of apparatus. Existing tools (BFT, Paxos) are purpose-built and sufficient.

6. Honest Assessment

HoTT-RO v2 is a specialized instrument. It was built for a specific ontology and tested within that ontology's empirical program. The fact that its formal properties have wider applicability is a consequence of having built on genuine structural foundations (HoTT, Univalence, type-theoretic identity) rather than ad hoc constructions.

The strongest external application is relational quantum mechanics, because AFM addresses a specific formal gap that existing formalizations of RQM do not fill. The second strongest is immunology, because the self/non-self problem has structural properties (contextual identity, continuous thresholds, bottleneck dynamics) that map directly onto **HoTT-RO v2**'s derived definitions.

For all other domains, **HoTT-RO v2** offers formal precision and ontological grounding but uncertain added predictive value over existing domain-specific tools. The test for any proposed application is the same as for the original project: does the formalization produce consequences that can be checked against data? If it produces only re-description — elegant but empirically inert — then the application is philosophical, not scientific.

The instrument exists. It is documented. It is publicly available. Whether anyone in these domains picks it up depends on whether they need what it provides — and whether they are willing to learn a

mathematical language that most practitioners in these fields have never encountered.

References

References

Lis, W. (2025). **The Self-Experiencing Universe: A Manifesto for an Emergent Reality**. https://www.amazon.com/dp/8396865183

Lis, W. (2026). **The Self-Experiencing Universe Q&A**

https://www.amazon.com/dp/8396865175

Lis, W. (2026). Ho TT FORMALIZATION — VERSION 1 Homotopy Type Theory Univalent Foundations × Relational Ontology - https://archive.org/details/ho-tt-formalization-version-1-homotopy-type-theory-univalent-foundations-x-relational-ontology

Lis, W. (2026). Ho TT FORMALIZATION — REVISION V 2 - https://archive.org/details/ho-tt-formalization-revision-v-2

Lis, W. (2026). THE MATHEMATICAL FOUNDATION Ho TT And The Relational Ontology Of The Self Experiencing Universe https://archive.org/details/the-mathematical-foundation-ho-tt-and-the-relational-ontology-of-the-self-experiencing-universe

Lis, W. (2026). Dynamics Validation Series: Simulations 14–19 https://archive.org/details/dynamics-validation-series-sim-14-19-full-technical_202604

Lis, W. (2026). COHERENCE STUDY Relational Ontology × Formal Mathematical Systems

https://archive.org/details/coherence-study-relational-ontology-x-formal-mathematical-systems

Lis, W. (2026). STRUCTURAL ISOMORPHISMS ∞ Categories And ∞ Toposes (Lurie) × Relational Ontology - https://archive.org/details/structural-isomorphisms-categories-and-toposes-lurie-x-relational-ontology

Univalent Foundations Program (2013). Homotopy Type Theory: Univalent Foundations of Mathematics. Institute for Advanced Study.

Lurie, J. (2009). Higher Topos Theory. Princeton University Press.

Martin-Löf, P. (1984). Intuitionistic Type Theory. Bibliopolis, Napoli.

Voevodsky, V. (2010). Univalent Foundations of Mathematics. IAS Lecture.

Rovelli, C. (1996). Relational Quantum Mechanics. International Journal of Theoretical Physics, 35(8), 1637–1678.

Gödel, K. (1931). Über formal unentscheidbare Sätze der Principia Mathematica. Monatshefte für Mathematik.

Waldemar Lis — April 2026
AI tools (Claude, Anthropic) were used in the analytical process; this is stated.
Full archive: archive.org/details/@not_foryou